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Final Report
Development of a Portable Infrared Emission Spectrometer
AA460 PIRES

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1. Project Summary

The purpose of this Phase II research effort was to design and build a prototype field portable thermal infrared emission spectrometer (PIRES). This phase of work would build on the design concepts and analysis completed during Phase I.

The AA460 PIRES System is a field-portable thermal emission spectral radiometer which operates over the 2.5-14.5 μm wavelength range. Its primary function is to characterize the spectral emission signatures of objects at reasonable terrestrial temperatures (0^{o}-50^{o}C). However, the instrument design is flexible enough to allow useful data collection to occur from objects outside this temperature range or from sources other than thermal radiators. While ideally suited for two-man operation in the field, the instrument can be transported and operated effectively by a single user. The AA460 PIRES System gives the user the capability to collect and display processed thermal emission data on-site. This eliminates the need for the user/researcher to remove a sample from its natural setting in order to accommodate laboratory analysis.

The AA460 PIRES instrument was fabricated, assembled, tested, and documented during this Phase II work period. Software development included a user friendly menu structure, control and communications processes. Testing included optical and spectral characterization of the instrument and general performance. The test results concluded that the instrument met most of the original design goals set forward in the Phase I work including size, weight, portability, rugged, menu driven operation and in-field analysis.

The area in which the instrument did not meet our design goals is in the signal-to-noise performance. Testing concluded that this poor SNR performance was due primarily to data collection scheme and our inability to properly amplify, and stabilize the detector signals. Modification to this collection scheme could improve the SNR performance and verification would be provided by additional laboratory testing. This performance improvement verification is necessary before implementation of a redesign to the optical head and its present data collection scheme.

2. Instrument Specifications

2.1. General Description

The AA460 PIRES System is a battery powered field-portable thermal emission spectral radiometer which operates over the 2.5-14.5 μm wavelength range. The complete instrument consists of two main assemblies, the sensor head and the backpack. The complete operational system is shown in Figure 1.

The sensor head assembly, outlined in Figure 2, consists of the imaging optics, a 2-element sandwich-type detector, an all-attitude liquid nitrogen (LN_2) dewar, an optical sight, a remote keyboard/display, two blackbody reference sources, instrument control electronics and mechanics, and a continuous variable filter (CVF) wheel. The backpack assembly primarily consists of a 12-volt battery and a portable control, processing, display, and storage computer. The backpack structure itself serves as a transportation and storage container for both the sensor head and the backpack assemblies. The backpack and the sensor head are electrically coupled by way of a multiconductor electrical cable over which numerous electrical signals travel.

2.1.1. Imaging Optics

The complete optical system consists of nine germanium lens elements and two deviating mirrors. These optical elements are used to:

- Define the instruments field-of-view (FOV)
- Image the energy through the CVF
- Image the energy onto the detector.

Figure 1. AA460 PIRES System

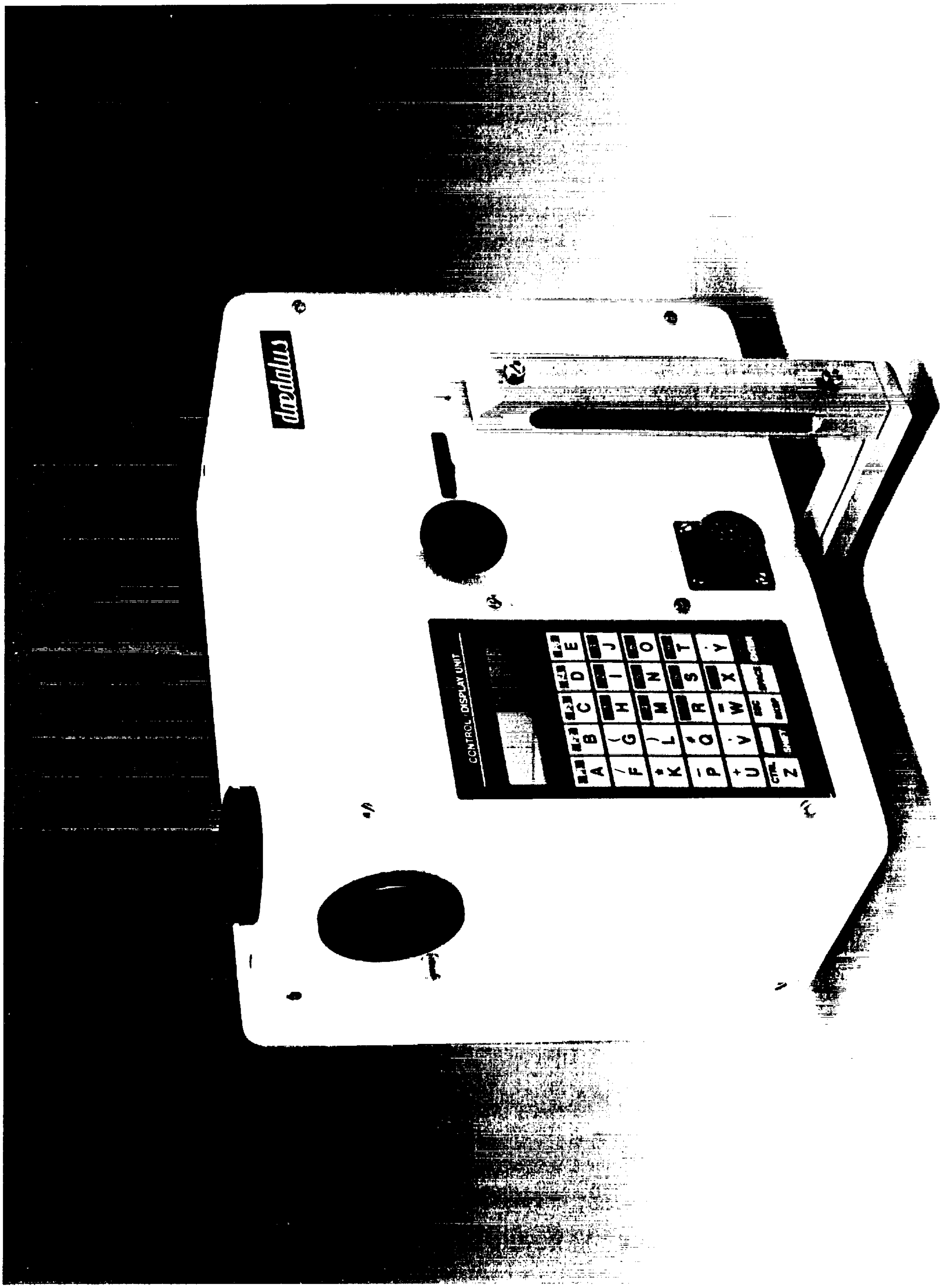


Figure 2. AA460 PIRES Sensor Head Assembly

The AA460 PIRES System provides the user with two selectable FOV's, 2^{o} and 8^{o}. The user can select to operate the instrument in either the 2^{o} or 8^{o} mode by throwing a mechanical switch located on the side of the sensor head.

2.1.2. Two-Element Detector

The detector which is used in the AA460 PIRES System is a 2-element sandwich-type detector. It consists of a thin layer of photovoltaic Indium Antimonide (InSb) over a layer of photoconductive Mercury Cadmium Telluride (MCT). InSb responds well in the 1-5.5 μm wavelength range while MCT responds well in the 5.5-15 μm wavelength range. Therefore, the use of a sandwich-type detector as described above ensures continuous satisfactory operation across the instruments 2.5-14.5 μm wavelength range. Both InSb and MCT require cryogenic cooling to LN_2 temperatures (77^{o}K) for proper operation.

2.1.3. All-Attitude LN_2 Dewar

Integral to the AA460 sensor head is an all-attitude LN_2 dewar. This dewar houses the instruments InSb/MCT sandwich detector. Once filled with LN_2, the dewar is specially designed to contain the LN_2 in all dewar positions, including upside down. This is a very important feature given the unpredictable nature of field operation. The all-attitude feature of the dewar makes transporting the instrument from site to site an easy procedure. In addition, it permits data collection to be performed in any conceivable instrument orientation. The hold time for a single charge of LN_2 is greater than 4 hours. That is, without refilling, a single charge of LN_2 will keep the instrument's sandwich detector at 77^{o}K for 4 hours or more.

2.1.4. Optical Sight

A FOV-defining optical sight is contained in the sensor head. It is co-aligned with the axis of the instruments imaging optics axis. By looking through the eyepiece of the sight, the user is simultaneously provided with both a 2^{o} FOV and 8^{o} FOV outline. The two FOV's are respectively defined by the small and large square targets visible in the sight.

The sight is continuously adjustable over a target distance ranging from 18 inches to ∞. Due to the nature in which the instruments primary optics defines the systems IFOV, the sight is most accurate in predicting true instrument FOV when the target is far from the instrument (∞). At closer distances the instruments true FOV is slightly larger than what is defined by the sight.

2.1.5. Remote Keyboard/Display

A small membrane keyboard and 16-character by 2-line display is integral to AA460 PIRES sensor head. This remote keyboard/display provides the user with the capability of collecting spectral data without the need to access the full capability, menu-driven operational software found in the backpack mounted portable computer. With its lack of graphing capabilities and its limited ability to prompt, the remote keyboard/display provides the user access to only a subset of the total PIRES operational capabilities. However, the operational functions which are accessible from it are very useful in allowing the user to collect data when it is either inconvenient or impossible to use the backpack mounted computer.

2.1.6. Blackbody References

The AA460 sensor head contains two temperature monitored blackbody reference sources. Both of these blackbody reference sources are viewed by the instrument during the course of a data collection sequence. One of the references is an ambient blackbody reference source. It is neither actively heated or cooled. The other reference source is a hot blackbody reference. During data collection, this blackbody is heated above the ambient temperature to a control temperature. It is held at this control temperature during the entire data collection procedure. Ambient and hot blackbody spectral information obtained during data collection is used to calibrate the measured scene data.

The inclusion of two internal blackbody reference sources into the AA460 PIRES head eliminates the need to transport external blackbody references sources to the field site.

2.1.7. Continuous Variable Filter

Spectral dispersion in the AA460 PIRES system is achieved with the use of a continuous variable filter (CVF) wheel assembly. Manufactured out of three individual filter segments, the filter wheel assembly used in the PIRES sensor head provides for narrowband spectral selection across the 2.5-14.5 μm wavelength range. CVF's consist of optical substrates coated with multi-layer dielectric films. The spectral characteristics of the CVF is dependent on the thickness of the individual film layers and the refractive indices of both the film layers and the substrate materials. In the case of a CVF, the substrate/dielectric films combination produces a narrowband spectral filter which maintains a linear relationship between wavelength of peak transmission and angular position on the filter segment. The variable filtering action produced as the CVF assembly is rotated in the sensor head is used to isolate and measure scene spectral information.

2.1.8. Battery

The AA460 PIRES system operates off a 12-volt battery. A Model PS-1265 12-volt sealed lead acid battery manufactured by Power Sonic Corp. is provided as part of the standard AA460 equipment. The battery is housed on the backpack structure. In addition, the system is mechanically and electrically designed to accept a 12-volt silver zinc battery. Silver zinc batteries are capable of delivering more data collection power as compared to lead acid batteries. However, they are significantly heavier and more expensive than lead acid type batteries. A battery design consisting of 8 Whitaker-

Yardney Power Systems silver zinc cells No. LR20DC-5 can be supplied to the user as an option.

2.1.9. On-Board Computer

Integral to the AA460 backpack assembly is small, lightweight, low-power portable computer. This computer is used to perform several instrument functions including sensor head control, data processing, data storage, and data display. The backpack computer is the primary user interface to the PIRES system operational software. It consists of a 640 x 400 fixed LCD graphics display, a 3-1/2 inch floppy drive and a full function keyboard. Using the keyboard and display simultaneously, the user has access to the AA460 menu driven operational software. In addition to controlling the instrument, the user can also use the backpack computer to graph raw detector data as well as processed spectral information. Data collected by the instrument is stored on 1.4 Mbyte 3-1/2 inch floppy diskettes. In addition to executing PIRES specific control and processing software, the AA460 backpack computer is capable of running various user defined application programs. This enhances the instruments flexibility and usefulness in the field.

2.1.10. Backpack Structure

The backpack frame design of the AA460 PIRES system makes site-to-site transportation of the instrument a relatively easy procedure. The backpack computer and battery are permanently fastened to a lightweight fiberglass epoxied aluminum honeycomb material. Despite its light weight, this material is extremely strong and durable and, thus, it provides structural integrity to the overall system packaging scheme. During transportation the sensor head is also secured to this honeycomb composite.

In order to facilitate single user transportation of the complete system, the main PIRES structural member is then mounted to a standard backpack frame. To accommodate a wide variety of instrument deployments, both in and out of the field, the backpack frame is designed to be quickly and easily removed from the rest of the unit. It is equally as easy to re-attach the pack frame to the rest of the backpack structure whenever needed.

2.2. Detailed Specifications

Listed below are some of the significant AA460 PIRES specifications.

Size:	Sensor Head: 6.5 in. x 8.4 in. x 10.8 in. Backpack: 9.0 in. x 16.4 in. x 33.5 in.
Weight:	Sensor Head: 10.2 lbs. Backpack: 25.0 lbs.
Environment:	Operating Temperature: $+5^{o}C$ - $+45^{o}C$ Storage Temperature: $-20^{o}C$ - $+60^{o}C$ Humidity (non-condensing): 10% - 90%
Spectral Coverage:	2.5 - 14.5 μm
Spectral Resolution:	$\leq$ 2% of λ. Given a single line source at λ_o, the half-power bandwidth of the displayed spectrum would be $\leq (0.02)\ \lambda_o$.
Noise Equivalent Temperature Difference (NETD):	$\leq 0.2^{o}C$ fom 4-14 μm (proposed)
Field of View:	User selectable, 2^{o} or 8^{o} square.
Data Acquisition Time:	Data Collection: Variable, depending on number of samples averaged.
Battery Life:	$\geq$ 200 spectra with fully charged lead acid battery. $\geq$ 1000 spectra with fully charged silver zinc battery

Liquid Nitrogen Hold Time:	≥ 4 hours
Dynamic Range:	12 bits
Data Display:	LCD graphics: 640 x 400 pixels Screen Size: 9 in. x 6 in.
Cable Lengths:	10 ft. (standard) 25 ft. (optional)
Data Storage:	1.4 Mbyte, 3-1/2 in. floppy diskette
Data Transfer:	Removable 3-1/2 in. floppy diskette; parallel printer port available for hardcopy transfer of LCD graphics information.
Sensor Head Mounting:	Hand-held or tripod mounting.

3. Performance

3.1. Testing

Testing and alignment of various system components were accomplished during fabrication. These included the following:

- Alignment of the complete imaging optical system
- CVF positioning for optimum spectral bandwidth
- Spectral calibration.

These tests showed that the design had achieved the two and eight degree fields of view and that the spectral bandwidth was approximately 2 percent of the wavelength and for approximately 2.60 μm – 14.5 μm with no gaps in coverage.

The spectral calibration was performed using a scanning McPherson monchrometer. The field of view of the instrument was filled with energy from the monchrometer using an off-axis parabola. Three separate gratings for the monchrometer were required to cover the broad spectral range. Data for wavelength position verse encoder step was determined for the 2.55μm – 12.5 μm by rotating the CVF and viewing the response on an oscilloscope. At 12.5 μm we could no longer get enough energy from the monchrometer and extrapolated the encoder position versus wavelength for the rest of the third segment. During this calibration process, spectral bandwidth was determined at several points on the CVF by scanning the monchrometer and determining the half-power points. At 9.0 μm the measured bandwidth was 1.96% and at 6.0 and 2.6 μm in the bandwidth was 1.98% and 1.52% respectively.

3.2. Signal/Noise Performance

The instrument signal-to-noise performance was calculated using a utility program embedded into the PIRES software. This program is used to convert raw data collected into wavelength dependent NETD information. The user selects the number of data samples to be collected and the NETD program statistically computes the measured sensitivity performance of the system. This raw data is then processed off line. Due to the extensive amounts of processing associated with this program, it is recommended that it be executed on either a 286 or 386 AT computer equipped with a math co-processor.

Using the data file produced during SNR data acquisition, we will statistically compute an SNR value at each wavelength for each detector. As mentioned before, these SNR algorithms will be contained in a stand-alone computer program. In order to statistically determine SNR in this manner, the signal energy which is supplied to the system must remain constant throughout the course of the SNR data acquisition operation. In our case, the signal of interest is the DIFFERENCE in radiance between the hot and ambient blackbody. The only way this signal can remain constant is for BOTH the blackbody temperatures to remain constant. It is anticipated that both the hot and ambient blackbody temperatures will vary somewhat during SNR data acquisition. The first step then in performing a SNR calculation is to go through the thermistor data line by line and select those data lines wherein both the hot and ambient blackbody counts fall within some user defined range. Hopefully the selected data will comprise a large subset of the total data collected. After this "good" data has been identified, the following operations will be performed on it.

$$A\lambda_1 n = \left(InSb\ Hot\right) - \left(InSb\ Ambient\right);$$

$$B\lambda_{??} n = \left(MCT\,Hot\right) - \left(MCT\,Ambient\right)\ mean\ InSb\ signal\ at\ \lambda = U\lambda =$$

$$\frac{\sum_n A\lambda_1 n}{\#\ of\ good\ InSb\ data\ lines\ at\ \lambda}$$

$$mean\ MCT\ signal\ at\ \lambda = \nu_\lambda = \frac{\sum_n B\lambda_1 n}{\#\ of\ good\ MCT\ data\ lines\ at}$$

$$standard\ deviation\ of\ InSb\ a\ \lambda = \sigma_{\nu\lambda} = \sqrt{\frac{\sum_n + \left[A\lambda_1 n - U\lambda\right]^2}{\#\ of\ good\ InSb\ data\ lines}}$$

$$standard\ deviation\ of\ MCT\ at\ \lambda = \sigma_{\nu\lambda} = \sqrt{\frac{\sum_n \left[B\lambda_1 n - \nu\lambda\right]^2}{\#\ of\ good\ MCT\ data\ lines}}$$

Now,

$$SNR\lambda,_{InSb} = \frac{U\lambda}{\sigma_{u\lambda}}$$

$$SNR\lambda, MCT = \frac{\gamma\lambda}{\sigma_{\gamma\lambda}}$$

These SNR values are outputted in tabular format listed below in Table 1.

TABLE 1.

There are 335 good wavelengths

Detector 1 Signal	Detector 2 Signal	Detector 1 Noise	Detector 2 Noise	Detector 1 NETD	Detector 2 NETD	System NETD	Wave lengt
0.000	41.105	0.000	1207.042	3.400e+038	2.320e+002	3.400e+038	2.608
0.000	431.250	255.660	1837.423	3.400e+038	3.366e+001	3.400e+038	2.625
0.000	0.000	402.200	1864.269	3.400e+038	3.400e+038	3.400e+038	2.643
0.000	59.529	380.687	2346.890	3.400e+038	3.114e+002	3.400e+038	2.661
0.000	329.500	453.697	1401.702	3.400e+038	3.361e+001	3.400e+038	2.678
0.000	184.167	365.321	1683.803	3.400e+038	7.223e+001	3.400e+038	2.696
0.000	0.000	351.940	2052.802	3.400e+038	3.400e+038	3.400e+038	2.714
0.000	0.000	356.845	2291.100	3.400e+038	3.400e+038	3.400e+038	2.731
0.000	186.188	460.532	1168.768	3.400e+038	4.959e+001	3.400e+038	2.749
0.000	0.000	404.451	2254.334	3.400e+038	3.400e+038	3.400e+038	2.767
0.000	0.000	238.748	2531.687	3.400e+038	3.400e+038	3.400e+038	2.784
0.000	0.000	396.056	2348.850	3.400e+038	3.400e+038	3.400e+038	2.802
0.000	0.000	359.523	1919.415	3.400e+038	3.400e+038	3.400e+038	2.820
0.000	0.000	396.920	1862.990	3.400e+038	3.400e+038	3.400e+038	2.837
0.000	48.938	232.279	2046.691	3.400e+038	3.304e+002	3.400e+038	2.855
0.000	0.000	313.250	2320.989	3.400e+038	3.400e+038	3.400e+038	2.873
0.000	0.000	324.097	2350.664	3.400e+038	3.400e+038	3.400e+038	2.890
0.000	0.000	336.544	3110.237	3.400e+038	3.400e+038	3.400e+038	2.908
0.000	0.000	294.510	2093.049	3.400e+038	3.400e+038	3.400e+038	2.926
0.000	0.000	297.243	2737.141	3.400e+038	3.400e+038	3.400e+038	2.943
0.000	0.000	414.212	2838.410	3.400e+038	3.400e+038	3.400e+038	2.961
0.000	0.000	341.295	2575.936	3.400e+038	3.400e+038	3.400e+038	2.979
0.000	0.000	291.413	2220.848	3.400e+038	3.400e+038	3.400e+038	2.996
0.000	0.000	325.479	2400.281	3.400e+038	3.400e+038	3.400e+038	3.014
0.000	0.000	343.553	2311.244	3.400e+038	3.400e+038	3.400e+038	3.032
0.000	0.000	303.232	2617.661	3.400e+038	3.400e+038	3.400e+038	3.049
0.000	0.000	338.766	2837.041	3.400e+038	3.400e+038	3.400e+038	3.067
0.000	0.000	375.985	2348.316	3.400e+038	3.400e+038	3.400e+038	3.085
0.000	0.000	395.616	2151.186	3.400e+038	3.400e+038	3.400e+038	3.102
0.000	0.000	369.860	1668.381	3.400e+038	3.400e+038	3.400e+038	3.120
0.000	0.000	296.843	3329.350	3.400e+038	3.400e+038	3.400e+038	3.138
0.000	0.000	377.304	3048.591	3.400e+038	3.400e+038	3.400e+038	3.155
0.000	0.000	356.741	2717.288	3.400e+038	3.400e+038	3.400e+038	3.173
0.000	0.000	391.691	2657.062	3.400e+038	3.400e+038	3.400e+038	3.191
0.000	0.000	319.557	2745.442	3.400e+038	3.400e+038	3.400e+038	3.208
0.000	0.000	306.768	2709.475	3.400e+038	3.400e+038	3.400e+038	3.226
0.000	0.000	320.413	2979.156	3.400e+038	3.400e+038	3.400e+038	3.244
0.000	0.000	415.450	3178.424	3.400e+038	3.400e+038	3.400e+038	3.261
0.000	0.000	376.220	3106.836	3.400e+038	3.400e+038	3.400e+038	3.279
0.000	0.000	299.471	3096.990	3.400e+038	3.400e+038	3.400e+038	3.297
0.000	0.000	489.495	3265.723	3.400e+038	3.400e+038	3.400e+038	3.314
0.000	0.000	418.111	2845.475	3.400e+038	3.400e+038	3.400e+038	3.332
0.000	0.000	409.657	3277.231	3.400e+038	3.400e+038	3.400e+038	3.350
0.000	0.000	399.243	2772.811	3.400e+038	3.400e+038	3.400e+038	3.367
0.000	0.000	358.369	2946.914	3.400e+038	3.400e+038	3.400e+038	3.385
0.000	0.000	385.409	3091.740	3.400e+038	3.400e+038	3.400e+038	3.403
0.000	0.000	356.598	2815.750	3.400e+038	3.400e+038	3.400e+038	3.420
0.000	0.000	396.776	2766.342	3.400e+038	3.400e+038	3.400e+038	3.438
0.000	0.000	354.330	3131.015	3.400e+038	3.400e+038	3.400e+038	3.456
0.000	0.000	461.624	2484.955	3.400e+038	3.400e+038	3.400e+038	3.473
0.000	0.000	348.971	2683.976	3.400e+038	3.400e+038	3.400e+038	3.491

0.000	0.000	263.065	3040.640	3.400e+038	3.400e+038	3.400e+038	3.509
0.000	0.000	303.765	3005.191	3.400e+038	3.400e+038	3.400e+038	3.526
0.000	0.000	319.242	3724.349	3.400e+038	3.400e+038	3.400e+038	3.544
0.000	0.000	422.971	3429.390	3.400e+038	3.400e+038	3.400e+038	3.562
0.000	0.000	329.686	3084.913	3.400e+038	3.400e+038	3.400e+038	3.579
0.000	0.000	448.368	2794.133	3.400e+038	3.400e+038	3.400e+038	3.597
0.000	0.000	350.915	2502.283	3.400e+038	3.400e+038	3.400e+038	3.615
0.000	0.000	322.107	3140.209	3.400e+038	3.400e+038	3.400e+038	3.632
0.000	0.000	441.574	3564.958	3.400e+038	3.400e+038	3.400e+038	3.650
0.000	0.000	360.545	3318.100	3.400e+038	3.400e+038	3.400e+038	3.668
0.000	0.000	383.318	3165.013	3.400e+038	3.400e+038	3.400e+038	3.685
0.000	0.000	452.859	2750.702	3.400e+038	3.400e+038	3.400e+038	3.703
0.000	0.000	419.844	3006.905	3.400e+038	3.400e+038	3.400e+038	3.721
0.000	0.000	392.247	3186.423	3.400e+038	3.400e+038	3.400e+038	3.738
0.000	0.000	379.302	3593.315	3.400e+038	3.400e+038	3.400e+038	3.756
0.000	0.000	396.429	2902.375	3.400e+038	3.400e+038	3.400e+038	3.774
0.000	0.000	359.109	3171.403	3.400e+038	3.400e+038	3.400e+038	3.791
0.000	0.000	465.979	3249.781	3.400e+038	3.400e+038	3.400e+038	3.809
0.000	0.000	368.784	2290.432	3.400e+038	3.400e+038	3.400e+038	3.827
0.000	0.000	393.776	3230.048	3.400e+038	3.400e+038	3.400e+038	3.844
0.000	0.000	397.220	3118.079	3.400e+038	3.400e+038	3.400e+038	3.862
0.000	0.000	389.814	3320.266	3.400e+038	3.400e+038	3.400e+038	3.880
0.000	0.000	361.482	3658.056	3.400e+038	3.400e+038	3.400e+038	3.897
0.000	0.000	404.946	3480.255	3.400e+038	3.400e+038	3.400e+038	3.915
0.000	0.000	487.707	3729.156	3.400e+038	3.400e+038	3.400e+038	3.933
0.000	0.000	366.024	3097.784	3.400e+038	3.400e+038	3.400e+038	3.950
0.000	0.000	437.745	3195.125	3.400e+038	3.400e+038	3.400e+038	3.968
0.000	0.000	362.901	3199.342	3.400e+038	3.400e+038	3.400e+038	3.986
0.000	0.000	477.694	3901.914	3.400e+038	3.400e+038	3.400e+038	4.003
0.000	0.000	470.391	3910.334	3.400e+038	3.400e+038	3.400e+038	4.021
0.000	0.000	427.367	3102.706	3.400e+038	3.400e+038	3.400e+038	4.039
0.000	0.000	509.730	3327.587	3.400e+038	3.400e+038	3.400e+038	4.056
0.000	0.000	447.755	3773.982	3.400e+038	3.400e+038	3.400e+038	4.074
0.000	0.000	443.658	3676.328	3.400e+038	3.400e+038	3.400e+038	4.092
0.000	0.000	536.893	3684.509	3.400e+038	3.400e+038	3.400e+038	4.109
0.000	0.000	604.390	3034.974	3.400e+038	3.400e+038	3.400e+038	4.127
0.000	0.000	619.304	3739.256	3.400e+038	3.400e+038	3.400e+038	4.145
0.000	0.000	553.320	3625.274	3.400e+038	3.400e+038	3.400e+038	4.162
0.000	0.000	514.963	3628.539	3.400e+038	3.400e+038	3.400e+038	4.180
0.000	0.000	338.943	3686.934	3.400e+038	3.400e+038	3.400e+038	4.198
0.000	0.000	204.346	3932.786	3.400e+038	3.400e+038	3.400e+038	4.215
0.000	0.000	24.256	3410.635	3.400e+038	3.400e+038	3.400e+038	4.233
0.000	0.000	0.000	4237.611	3.400e+038	3.400e+038	3.400e+038	4.251
0.000	0.000	0.000	3934.695	3.400e+038	3.400e+038	3.400e+038	4.268
0.000	0.000	0.000	3779.190	3.400e+038	3.400e+038	3.400e+038	4.286
0.000	0.000	0.000	4101.958	3.400e+038	3.400e+038	3.400e+038	4.304
0.000	0.000	0.000	3849.837	3.400e+038	3.400e+038	3.400e+038	4.322
0.000	0.000	0.000	3894.481	3.400e+038	3.400e+038	3.400e+038	4.339
283.000	1319.000	326.683	302.642	9.119e+000	1.813e+000	9.119e+000	4.452
3531.500	0.000	686.023	1578.756	1.535e+000	3.400e+038	1.535e+000	4.484
3913.000	0.000	675.299	1325.880	1.363e+000	3.400e+038	1.363e+000	4.516
3932.125	0.000	666.980	2251.925	1.340e+000	3.400e+038	1.340e+000	4.547
4071.688	332.750	595.340	1396.150	1.155e+000	3.315e+001	1.155e+000	4.579
4255.600	0.000	384.319	1854.704	7.134e-001	3.400e+038	7.134e-001	4.611
4471.842	0.000	627.981	1591.140	1.109e+000	3.400e+038	1.109e+000	4.642
4592.941	262.235	664.900	1456.887	1.144e+000	4.389e+001	1.144e+000	4.674

4930.210	0.000	680.575	2120.523	1.091e+000	3.400e+038	1.091e+000	4.706
5123.611	0.000	613.038	1744.230	9.452e-001	3.400e+038	9.452e-001	4.737
5413.933	142.467	649.298	1465.869	9.475e-001	8.128e+001	9.475e-001	4.769
5689.750	0.000	646.915	1214.122	8.982e-001	3.400e+038	8.982e-001	4.801
5982.000	0.000	632.657	1770.251	8.355e-001	3.400e+038	8.355e-001	4.832
6189.750	0.000	548.180	1462.020	6.996e-001	3.400e+038	6.996e-001	4.864
6586.611	0.000	583.158	1521.556	6.994e-001	3.400e+038	6.994e-001	4.896
6888.333	412.111	655.269	1832.866	7.515e-001	3.514e+001	7.515e-001	4.927
7225.222	259.500	608.081	1638.145	6.649e-001	4.987e+001	6.649e-001	4.959
7493.882	227.118	589.588	1199.740	6.215e-001	4.173e+001	6.215e-001	4.991
7942.111	0.000	701.258	1577.169	6.975e-001	3.400e+038	6.975e-001	5.022
8292.190	0.000	592.814	2050.529	5.648e-001	3.400e+038	5.648e-001	5.054
8665.777	299.944	689.175	1953.696	6.283e-001	5.146e+001	6.283e-001	5.086
9083.059	248.235	684.574	1504.550	5.954e-001	4.788e+001	5.954e-001	5.117
9462.823	1015.941	731.300	2065.949	6.105e-001	1.606e+001	6.105e-001	5.149
9918.714	104.143	822.289	1796.294	6.549e-001	1.363e+002	6.549e-001	5.181
10326.066	0.000	381.982	1644.268	2.922e-001	3.400e+038	2.922e-001	5.212
10821.053	206.737	662.176	1739.687	4.834e-001	6.648e+001	4.834e-001	5.244
11247.632	442.526	693.396	2040.559	4.870e-001	3.643e+001	4.870e-001	5.275
11727.500	60.889	744.778	2150.688	5.017e-001	2.790e+002	5.017e-001	5.307
12116.059	339.353	760.684	1599.153	4.960e-001	3.723e+001	4.960e-001	5.339
12278.050	0.000	629.919	1683.146	4.053e-001	3.400e+038	4.053e-001	5.370
12326.625	210.625	577.428	1274.974	3.701e-001	4.782e+001	3.701e-001	5.402
11714.200	791.500	710.126	1835.369	4.789e-001	1.832e+001	4.789e-001	5.434
10492.350	974.600	633.772	1224.602	4.772e-001	9.926e+000	4.772e-001	5.465
8558.277	623.722	468.224	1956.549	4.322e-001	2.478e+001	4.322e-001	5.497
6902.500	800.429	560.143	1918.579	6.411e-001	1.894e+001	6.411e-001	5.529
4927.412	1070.412	444.221	1778.747	7.122e-001	1.313e+001	7.122e-001	5.560
3706.750	975.050	481.408	1712.470	1.026e+000	1.387e+001	1.026e+000	5.592
2856.368	1470.579	489.093	1740.687	1.353e+000	9.351e+000	1.353e+000	5.624
2329.563	1142.313	500.039	1306.250	1.696e+000	9.034e+000	1.696e+000	5.655
1935.722	1744.111	545.574	1853.100	2.227e+000	8.394e+000	2.227e+000	5.687
1687.857	2453.572	425.378	1840.161	1.991e+000	5.925e+000	1.991e+000	5.719
1395.737	2270.474	486.575	1391.358	2.754e+000	4.841e+000	2.754e+000	5.750
1282.773	2423.955	360.711	1820.325	2.221e+000	5.933e+000	5.933e+000	5.782
1166.722	1887.333	348.727	1415.952	2.361e+000	5.927e+000	5.927e+000	5.814
960.850	1842.600	432.597	1768.022	3.557e+000	7.580e+000	7.580e+000	5.845
802.000	2376.529	370.620	1657.823	3.651e+000	5.511e+000	5.511e+000	5.877
775.333	1607.800	248.385	1907.423	2.531e+000	9.372e+000	9.372e+000	5.909
680.133	1982.200	369.155	1887.401	4.288e+000	7.522e+000	7.522e+000	5.940
572.688	1625.188	394.312	1539.302	5.439e+000	7.483e+000	7.483e+000	5.972
561.250	2372.250	375.763	1615.939	5.289e+000	5.381e+000	5.381e+000	6.004
356.588	2266.588	277.422	1801.964	6.146e+000	6.281e+000	6.281e+000	6.035
382.318	2153.000	413.550	1824.474	8.545e+000	6.695e+000	6.695e+000	6.067
290.000	2044.750	340.435	2226.906	9.274e+000	8.604e+000	8.604e+000	6.099
357.600	2434.250	469.025	1888.858	1.036e+001	6.130e+000	6.130e+000	6.130
355.500	1928.667	418.507	2049.615	9.300e+000	8.395e+000	8.395e+000	6.162
421.389	1979.333	443.917	1655.080	8.322e+000	6.606e+000	6.606e+000	6.193
258.421	2214.632	367.843	2082.284	1.125e+001	7.428e+000	7.428e+000	6.225
313.000	1629.474	414.432	2110.140	1.046e+001	1.023e+001	1.023e+001	6.257
294.400	2153.200	550.609	1884.229	1.478e+001	6.913e+000	6.913e+000	6.288
301.100	2183.900	351.582	1719.896	9.224e+000	6.222e+000	6.222e+000	6.320
259.353	2073.529	422.533	1516.045	1.287e+001	5.776e+000	5.776e+000	6.352
327.421	2071.790	391.523	1890.693	9.447e+000	7.209e+000	7.209e+000	6.383
265.842	1518.895	333.878	2343.202	9.922e+000	1.219e+001	1.219e+001	6.415
231.500	2255.143	388.469	2180.657	1.326e+001	7.639e+000	7.639e+000	6.447

259.563	2344.000	347.895	1889.502	1.059e+001	6.368e+000	6.368e+000	6.478
288.900	1883.650	438.087	2061.959	1.198e+001	8.648e+000	8.648e+000	6.510
265.684	1764.737	352.041	2374.857	1.047e+001	1.063e+001	1.063e+001	6.542
218.824	2000.588	256.673	1970.250	9.266e+000	7.780e+000	7.780e+000	6.573
198.824	1281.765	328.579	1717.289	1.306e+001	1.058e+001	1.058e+001	6.605
136.250	2182.188	215.258	1522.333	1.248e+001	5.511e+000	5.511e+000	6.637
138.333	1960.889	327.813	1686.105	1.872e+001	6.793e+000	6.793e+000	6.668
65.333	2469.444	405.388	2306.000	4.902e+001	7.377e+000	7.377e+000	6.700
227.222	2316.222	316.531	1951.667	1.101e+001	6.657e+000	6.657e+000	6.732
167.778	2104.944	326.177	1927.928	1.536e+001	7.236e+000	7.236e+000	6.763
134.813	1640.813	284.087	1834.830	1.665e+001	8.834e+000	8.834e+000	6.795
62.625	2746.688	282.983	1927.442	3.570e+001	5.544e+000	5.544e+000	6.827
62.111	2138.833	374.759	2048.804	4.767e+001	7.567e+000	7.567e+000	6.858
119.111	2847.556	286.809	2397.902	1.902e+001	6.653e+000	6.653e+000	6.890
73.150	1824.200	292.351	1447.248	3.157e+001	6.268e+000	6.268e+000	6.922
105.750	1586.375	258.470	1577.192	1.931e+001	7.854e+000	7.854e+000	6.953
105.842	887.211	242.754	2057.414	1.812e+001	1.832e+001	1.832e+001	6.985
64.875	1258.813	290.389	2197.256	3.536e+001	1.379e+001	1.379e+001	7.017
27.789	1779.474	318.082	1861.020	9.042e+001	8.262e+000	8.262e+000	7.048
25.647	2141.235	269.760	2159.770	8.309e+001	7.968e+000	7.968e+000	7.080
33.579	1678.421	312.312	1979.450	7.348e+001	9.317e+000	9.317e+000	7.111
31.611	1914.889	322.918	1832.902	8.070e+001	7.562e+000	7.562e+000	7.143
137.375	1399.500	341.676	1751.105	1.965e+001	9.885e+000	9.885e+000	7.175
207.263	1808.000	297.173	2219.126	1.133e+001	9.696e+000	9.696e+000	7.206
0.000	1281.188	330.811	1903.697	3.400e+038	1.174e+001	1.174e+001	7.238
192.632	1741.263	315.001	2368.177	1.292e+001	1.074e+001	1.074e+001	7.270
34.647	2015.882	241.730	1940.801	5.512e+001	7.606e+000	7.606e+000	7.301
78.833	1945.389	293.790	1890.195	2.944e+001	7.676e+000	7.676e+000	7.333
44.111	1799.056	297.635	2632.236	5.330e+001	1.156e+001	1.156e+001	7.365
0.000	2288.294	287.823	1743.806	3.400e+038	6.020e+000	6.020e+000	7.396
0.000	2206.533	333.957	1749.863	3.400e+038	6.265e+000	6.265e+000	7.428
0.000	1673.211	263.281	1707.927	3.400e+038	8.064e+000	8.064e+000	7.460
0.000	1824.944	195.592	2557.389	3.400e+038	1.107e+001	1.107e+001	7.491
73.412	2193.882	187.277	1762.943	2.015e+001	6.348e+000	6.348e+000	7.523
0.000	2119.450	0.000	2142.435	3.400e+038	7.986e+000	7.986e+000	7.555
0.000	1474.412	311.606	1964.235	3.400e+038	1.052e+001	1.052e+001	7.586
0.000	2007.250	262.695	2109.517	3.400e+038	8.302e+000	8.302e+000	7.618
0.000	2052.526	236.059	1897.060	3.400e+038	7.302e+000	7.302e+000	7.650
0.000	1981.611	207.786	1520.876	3.400e+038	6.063e+000	6.063e+000	7.681
0.000	1929.357	339.574	1975.190	3.400e+038	8.088e+000	8.088e+000	7.713
0.000	1716.650	251.114	2021.047	3.400e+038	9.301e+000	9.301e+000	7.745
0.000	1229.529	259.477	2292.868	3.400e+038	1.473e+001	1.473e+001	7.776
0.000	2140.944	333.212	2194.842	3.400e+038	8.099e+000	8.099e+000	7.808
0.000	1630.556	243.145	1898.993	3.400e+038	9.201e+000	9.201e+000	7.840
0.000	1672.529	280.306	2531.592	3.400e+038	1.196e+001	1.196e+001	7.871
0.000	1608.389	274.106	2655.602	3.400e+038	1.304e+001	1.304e+001	7.903
0.000	1429.286	248.192	2173.975	3.400e+038	1.202e+001	1.202e+001	7.935
0.000	1693.545	262.600	1675.250	3.400e+038	7.815e+000	7.815e+000	7.966
0.000	2015.056	286.279	1881.002	3.400e+038	7.374e+000	7.374e+000	7.998
0.000	1433.100	31812.254	2151.540	3.400e+038	1.186e+001	1.186e+001	8.029
543.813	5230.313	287.168	1446.265	4.172e+000	2.184e+000	2.184e+000	8.060
0.000	5192.938	350.637	1707.063	3.400e+038	2.597e+000	2.597e+000	8.118
0.000	5894.889	367.004	1697.915	3.400e+038	2.275e+000	2.275e+000	8.176
0.000	5168.000	350.087	2233.568	3.400e+038	3.414e+000	3.414e+000	8.234
0.000	5662.263	340.774	2191.807	3.400e+038	3.058e+000	3.058e+000	8.293
0.000	6550.059	475.236	1817.600	3.400e+038	2.192e+000	2.192e+000	8.351

0.000	6571.200	412.015	1757.840	3.400e+038	2.113e+000	2.113e+000	8.409
0.000	6095.611	364.684	1669.698	3.400e+038	2.164e+000	2.164e+000	8.467
0.000	6615.813	443.117	1885.846	3.400e+038	2.252e+000	2.252e+000	8.526
0.000	6704.867	401.800	1912.480	3.400e+038	2.253e+000	2.253e+000	8.584
0.000	6816.000	337.834	2156.193	3.400e+038	2.499e+000	2.499e+000	8.642
0.000	7731.750	339.837	2288.015	3.400e+038	2k1H0.000	7789.950	365.9
0.000	8457.556	356.962	2415.671	3.400e+038	2.256e+000	2.256e+000	9.050
0.000	8907.833	327.279	1930.668	3.400e+038	1.712e+000	1.712e+000	9.108
0.000	4776.875	270.933	16727.809	3.400e+038	2.766e+001	2.766e+001	9.166
0.000	9002.471	372.347	2383.026	3.400e+038	2.091e+000	2.091e+000	9.225
0.000	9452.850	265.882	2270.233	3.400e+038	1.897e+000	1.897e+000	9.283
0.000	10223.389	336.782	2247.302	3.400e+038	1.737e+000	1.737e+000	9.341
0.000	10783.579	379.366	1869.030	3.400e+038	1.369e+000	1.369e+000	9.399
0.000	10864.294	326.252	2448.847	3.400e+038	1.781e+000	1.781e+000	9.458
0.000	6642.000	339.193	15793.234	3.400e+038	1.878e+001	1.878e+001	9.516
0.000	10685.046	316.393	2018.843	3.400e+038	1.493e+000	1.493e+000	9.574
0.000	11284.737	328.426	1790.930	3.400e+038	1.254e+000	1.254e+000	9.633
0.000	7592.474	395.222	14049.228	3.400e+038	1.462e+001	1.462e+001	9.691
0.000	7482.369	367.670	14128.035	3.400e+038	1.492e+001	1.492e+001	9.749
0.000	10899.842	337.847	1637.854	3.400e+038	1.187e+000	1.187e+000	9.807
0.000	11391.000	297.161	2065.828	3.400e+038	1.433e+000	1.433e+000	9.866
0.000	11813.190	313.501	2221.689	3.400e+038	1.486e+000	1.486e+000	9.924
0.000	12131.842	243.769	1658.138	3.400e+038	1.080e+000	1.080e+000	9.982
74.474	12136.263	358.285	1691.318	3.801e+001	1.101e+000	1.101e+000	10.04
0.000	12574.588	322.892	2704.990	3.400e+038	1.699e+000	1.699e+000	10.09
0.000	13212.875	384.768	2604.258	3.400e+038	1.557e+000	1.557e+000	10.15
3.263	13261.632	307.537	2173.139	7.445e+002	1.295e+000	1.295e+000	10.21
9.263	12666.737	284.575	2569.416	2.427e+002	1.602e+000	1.602e+000	10.27
6.474	12187.315	304.355	2043.970	3.714e+002	1.325e+000	1.325e+000	10.33
0.000	12846.000	254.994	2116.238	3.400e+038	1.301e+000	1.301e+000	10.39
0.000	12575.167	404.528	1886.265	3.400e+038	1.185e+000	1.185e+000	10.44
0.000	12165.375	328.257	2036.333	3.400e+038	1.322e+000	1.322e+000	10.50
1.313	12689.688	364.288	2077.485	2.193e+003	1.293e+000	1.293e+000	10.56
0.000	12079.158	323.103	1760.546	3.400e+038	1.151e+000	1.151e+000	10.62
78.412	11549.529	298.528	2210.316	3.008e+001	1.512e+000	1.512e+000	10.68
18.895	12084.105	264.876	2092.744	1.107e+002	1.368e+000	1.368e+000	10.73
36.938	12385.375	395.012	1304.631	8.448e+001	8.322e-001	8.322e-001	10.79
14.947	11566.263	363.948	2420.477	1.924e+002	1.653e+000	1.653e+000	10.85
0.000	11292.944	263.000	1871.288	3.400e+038	1.309e+000	1.309e+000	10.91
0.000	11189.929	217.423	2670.396	3.400e+038	1.885e+000	1.885e+000	10.97
0.000	11282.066	246.393	1433.759	3.400e+038	1.004e+000	1.004e+000	11.03
1.556	10615.556	310.332	1806.534	1.576e+003	1.344e+000	1.344e+000	11.08
31.000	9466.526	213.889	1658.015	5.451e+001	1.384e+000	1.384e+000	11.14
38.000	10197.450	215.142	1908.535	4.473e+001	1.479e+000	1.479e+000	11.20
0.000	10507.883	206.965	2429.462	3.400e+038	1.827e+000	1.827e+000	11.26
0.000	8860.200	0.000	1879.761	3.400e+038	1.676e+000	1.676e+000	11.32
118.600	8631.450	283.224	2164.389	1.887e+001	1.981e+000	1.981e+000	11.38
4.158	7740.105	285.611	2289.050	5.427e+002	2.336e+000	2.336e+000	11.43
14.000	7208.765	219.928	1797.988	1.241e+002	1.970e+000	1.970e+000	11.49
113.895	7052.421	243.689	2455.607	1.690e+001	2.751e+000	2.751e+000	11.55
27.563	6219.125	365.685	2783.828	1.048e+002	3.536e+000	3.536e+000	11.61

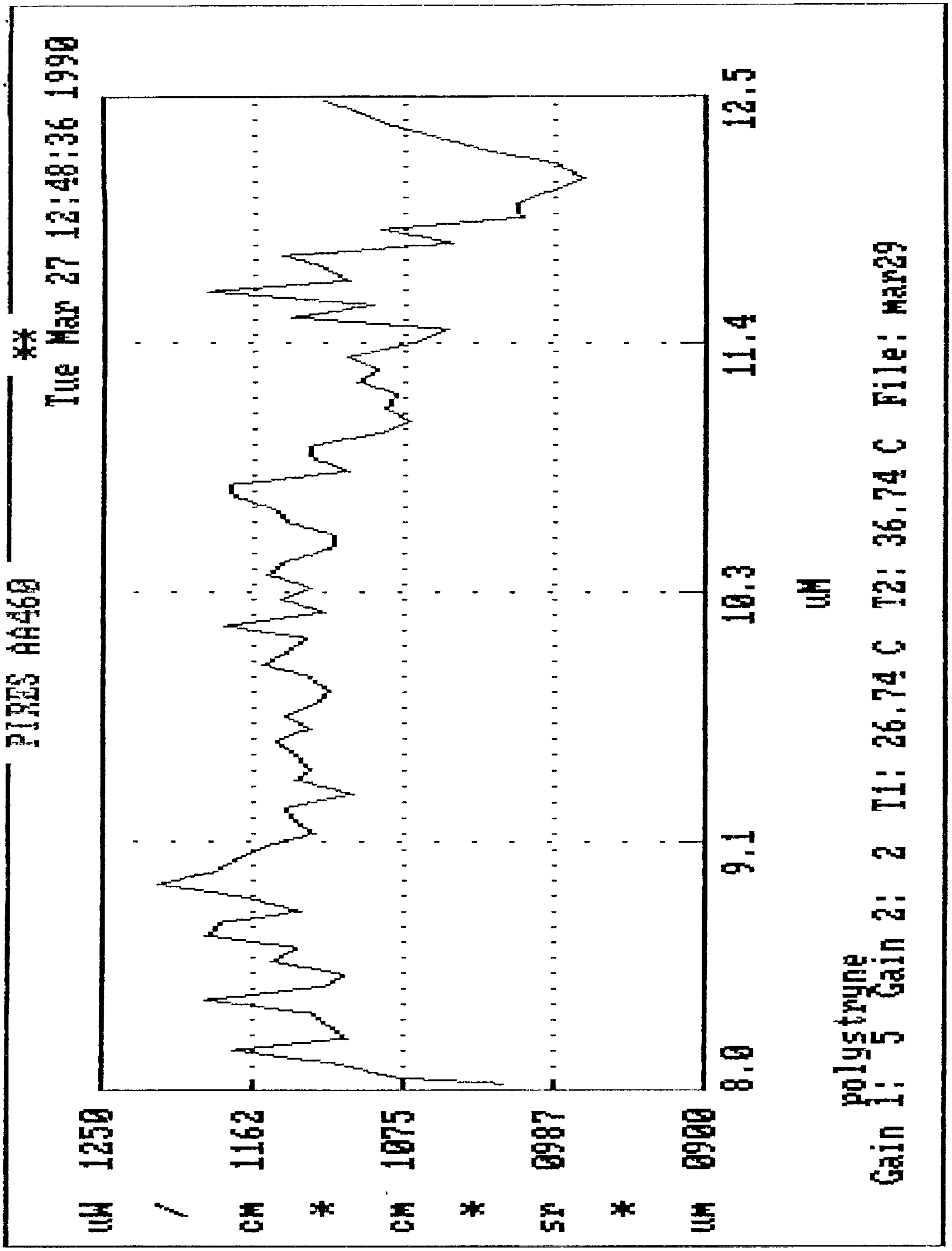
119.667	3356.000	391.171	2317.928	2.582e+001	5.456e+000	5.456e+000	11.96
26.722	3037.222	331.245	1806.045	9.793e+001	4.698e+000	4.698e+000	12.02
0.000	2396.833	344.420	2130.769	3.400e+038	7.023e+000	7.023e+000	12.07
0.000	3011.619	349.028	2154.140	3.400e+038	5.651e+000	5.651e+000	12.13
93.313	2007.188	366.519	2018.713	3.103e+001	7.945e+000	7.945e+000	12.19
0.000	2417.842	326.220	1943.070	3.400e+038	6.349e+000	6.349e+000	12.25
185.263	2451.842	332.465	2183.353	1.418e+001	7.035e+000	7.035e+000	12.31
30.667	2388.000	423.747	2558.676	1.092e+002	8.465e+000	8.465e+000	12.37
0.000	1922.619	317.746	1731.590	3.400e+038	7.115e+000	7.115e+000	12.42
118.563	1927.375	397.639	1792.894	2.650e+001	7.349e+000	7.349e+000	12.48
93.000	1708.688	318.868	1848.098	2.709e+001	8.545e+000	8.545e+000	12.54
0.000	1730.778	350.914	1848.280	3.400e+038	8.436e+000	8.436e+000	12.60
22.556	1572.444	334.737	2321.177	1.172e+002	1.166e+001	1.166e+001	12.66
79.111	1866.056	344.596	2054.227	3.441e+001	8.697e+000	8.697e+000	12.72
0.000	1323.300	355.983	1924.225	3.400e+038	1.149e+001	1.149e+001	12.77
49.222	1256.000	455.901	1488.435	7.317e+001	9.362e+000	9.362e+000	12.83
0.000	1682.400	400.184	2179.733	3.400e+038	1.024e+001	1.024e+001	12.89
116.625	1833.188	378.239	2208.448	2.562e+001	9.517e+000	9.517e+000	12.95
103.375	1180.938	336.062	2000.597	2.568e+001	1.338e+001	1.338e+001	13.01
33.857	1708.476	482.192	1776.698	1.125e+002	8.215e+000	8.215e+000	13.07
11.524	1246.571	431.363	2166.021	2.957e+002	1.373e+001	1.373e+001	13.12
0.000	9.105	235.787	1414.857	3.400e+038	1.228e+003	1.228e+003	13.18
68.905	896.476	425.334	2041.820	4.876e+001	1.799e+001	1.799e+001	13.24
0.000	1311.533	496.333	2570.092	3.400e+038	1.548e+001	1.548e+001	13.30
0.000	685.375	452.591	2283.327	3.400e+038	2.632e+001	2.632e+001	13.36
0.000	338.143	365.122	1996.302	3.400e+038	4.664e+001	4.664e+001	13.41
0.000	254.278	420.468	1996.446	3.400e+038	6.203e+001	6.203e+001	13.47
10.200	832.600	324.157	2201.471	2.511e+002	2.089e+001	2.089e+001	13.53
0.000	182.933	493.305	2188.993	3.400e+038	9.453e+001	9.453e+001	13.59
47.263	418.368	489.397	1997.043	8.180e+001	3.771e+001	3.771e+001	13.65
0.000	0.000	560.510	1776.303	3.400e+038	3.400e+038	3.400e+038	13.71
30.947	335.737	546.854	1538.528	1.396e+002	3.620e+001	3.620e+001	13.76
92.412	414.235	471.856	2080.471	4.034e+001	3.968e+001	3.968e+001	13.82
35.500	0.000	463.121	1979.749	1.031e+002	3.400e+038	3.400e+038	13.88
16.444	163.222	497.227	1824.976	2.389e+002	8.833e+001	8.833e+001	13.94
39.353	54.000	506.469	1858.573	1.017e+002	2.719e+002	2.719e+002	14.00
113.412	587.941	403.222	2232.689	2.809e+001	3.000e+001	3.000e+001	14.06
0.000	242.875	465.626	2193.052	3.400e+038	7.133e+001	7.133e+001	14.11
41.235	0.000	489.215	2053.823	9.373e+001	3.400e+038	3.400e+038	14.17
22.353	0.000	523.445	1545.721	1.850e+002	3.400e+038	3.400e+038	14.23
80.600	0.000	476.845	1580.433	4.674e+001	3.400e+038	3.400e+038	14.29
155.700	162.950	465.806	1583.658	2.363e+001	7.678e+001	7.678e+001	14.35
179.000	357.737	338.495	2066.026	1.494e+001	4.562e+001	4.562e+001	14.41
77.400	661.867	421.358	1874.919	4.301e+001	2.238e+001	2.238e+001	14.46
88.474	0.000	483.801	1841.263	4.320e+001	3.400e+038	3.400e+038	14.70
63.800	0.000	532.582	0.000	6.595e+001	3.400e+038	3.400e+038	14.75

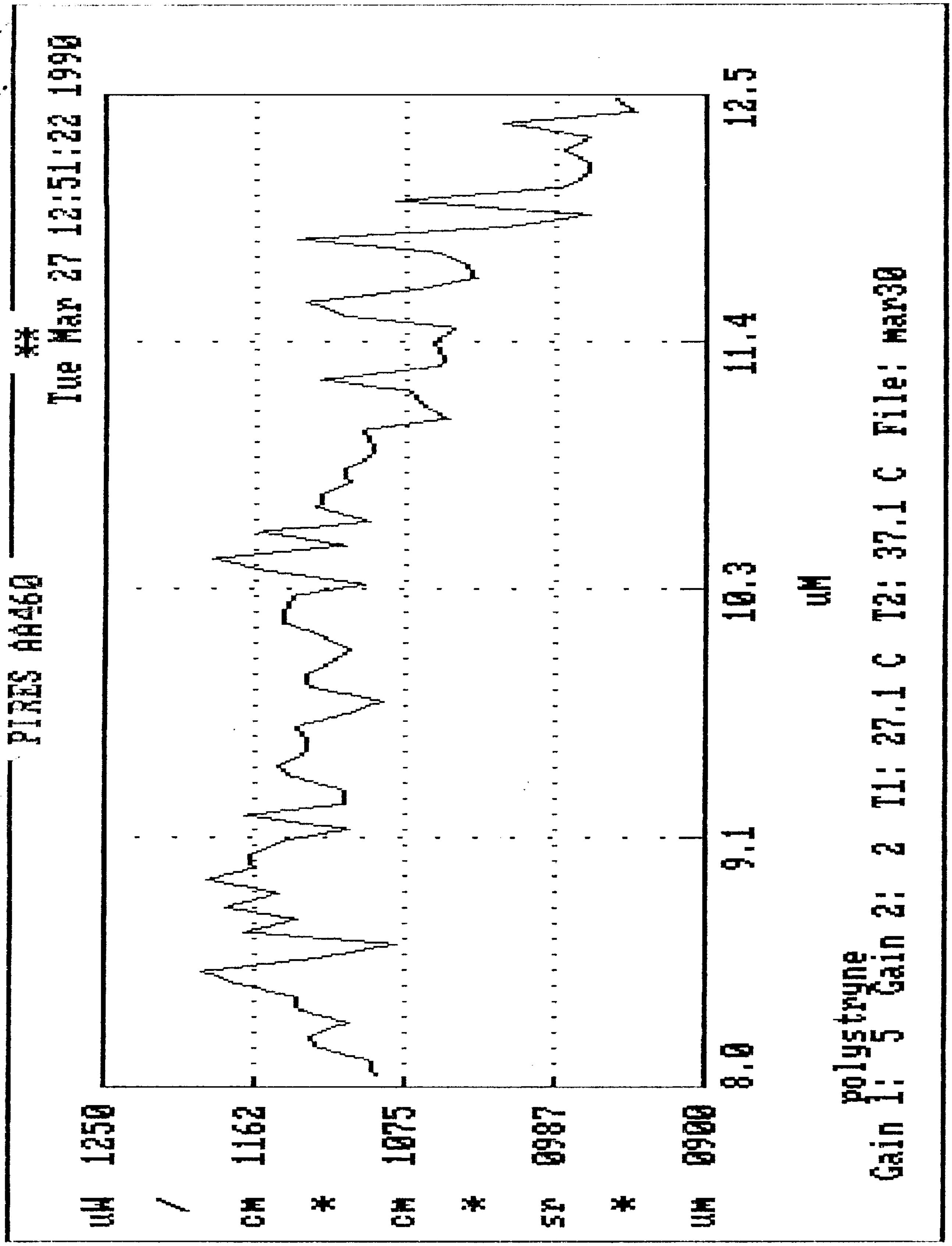
As you can see from this data, the instrument has measurable performance in only two wavelength areas. These are the 4.4 μm – 5.5 μm and 8.2 – 11.5 μm region which correspond to peak response areas of the InSb and MCT detector elements. The original instrument performance analysis completed in the Phase I work predicated NEDT performance of approximately one order of magnitude better than the measured values.

The Phase I analysis was based on a slightly different instrument design that chopped the input radiation against the reference sources and CVF motion was controlled by a stepper motor. This design required an electronic bandwidth of approximately 400 Hz. The Phase II development work concluded that with CVF stepper motion it would be impossible to implement a data collection time of 3 seconds. Tests showed that a minimum of 6 seconds might be possible with a highly developed mechanical damping mechanism needed to provide reliable non-jittering steps of the CVF. A more reasonable design would provide data acquisition in about 10 seconds. We felt that this would be unacceptable for a hand-held instrument. In addition, the dual choppers required to provide two blackbody reference sources had made the overall optical head size very large and heavy for a hand-held instrument. An alternate concept was pursued during the Phase II work and a design developed which eliminated the chopping of the input radiation against references. This scheme used a small reference and target mirrors to view first the ambient reference for a complete CVF rotation, then the target for another CVF rotation and finally the hot reference for a final CVF rotation.

This data acquisition scheme required that the CVF be rotated at a high rate of approximately 1000 revolutions per minute. This increased CVF rotation rate causes the system bandwidth requirements to increase. We concluded that we could average multiple CVF samples to maintain the original SNR requirements. Several consequences of this data collection scheme is the large variation in analog detector signals from segment to segment of the CVF. This is mainly due to the variation in detector response over the large wavelength region. The second problem area is the stabilization of the detector signals as the data is being averaged over all three targets. The analog signal processing include an analog clamp to stabilize the detector signals. This clamp was applied three times per CVF revolution when the detectors were looking at surface mirror section installed in between the CVF segments. These cold spikes are very constant and stable except for detector/preamp white noise and system noise. The large analog detector variation and cold spike sampling stabilization limited us to relatively low preamp gains to keep the analog signal out of saturation, including the cold spike clamping region. Our inability to properly amplify the detector signals and maintain the detector stabilization while data is gathered over the references and target is the main reason for poor instrument performance. The original data collection scheme of optical choppers and CVF steppers would allow proper amplification of these very low level analog signals without the need for clamping and offsetting circuits. In addition, a lock-in amplifier signal processing design could be implemented where in only the chopped frequency of the analog signal is used for processing.

As a further verification of poor instrument performance, spectra of polystyrene were obtained using the PIRES instrument; these are included in the following graphs. As you can see from these graphs, the processed radiance spectral data appears noisy and inconsistent for data taken over the same sample.


PIRES AA460
Tue Mar 27 12:48:36 1990
uM / cm * cm * sr * um
1250
1162
1075
0987
0900
8.0
9.1
10.3
11.4
12.5
uM
polystryne
Gain 1: 5 Gain 2: 2 T1: 26.74 C T2: 36.74 C File: mar29


PIRES AA460
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1250
1162
1075
0987
0900
8.0
9.1
10.3
11.4
12.5
uM
polystryne
Gain 1: 5 Gain 2: 2 T1: 27.1 C T2: 37.1 C File: mar30

4. Recommendations

The PIRES instrument, in its present form, needs improvement in its SNR performance in all wavelength regions. This further instrument development could be approached in the following ways.

The first approach is to continue with the present data collection scheme and improve SNR by better detector stabilization electronics for many rotations of the CVF, reducing systematic instrument noise in the analog detector signals, and providing better analog signal processing including improved offset removal and amplification of detector signal. This approach I feel will only lead to slight SNR improvements in the present instrument.

A better alternative would be to redesign the fore optics of the instrument to include optical choppers as originally proposed. This altered data collection scheme would then allow a dramatic decrease in system bandwidth requirements and, hence, improved SNR. In addition, I would recommend the CVF motor be changed to start and stop (stepper motor driven). This could easily be accomplished by replacement of the brushless DC motor with a stepper type. The present belt-driven driver pulleys could be modified to provide proper CVF motion per motor step. Signal-to-noise improvement using this approach should be verified by temporarily modifying the PIRES instrument to incorporate a stepper CVF drive and an ambient blackbody chopper inserted in the primary optical path. Detector signals could be bandwidth limited using laboratory filter and RMS-to-DC converted. This converted data could then be digitized and analyzed to verify improved system performance before undertaking the major optical head redesign to incorporate these features.

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